AR-742

An Evaluation of Cooling Tower Plume Studies Done for the Brayton Point Generating Station

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MFG was asked by EPA and TetraTech to evaluate studies conducted by TRC and EarthTech regarding the modification of the Brayton Point generating station to incorporate mechanical draft cooling towers. The Brayton Point Generating Station is a large, coal-fired electric generating facility with a maximum generation capability of 1,600 MW. Present cooling for the facility is provided by single-pass contact with salt water from the adjacent Bay. To prevent impact resulting from this thermal waste on the biological system in the Bay, EPA is considering requiring the Brayton Point facility to reduce both water intake and thermal discharge to the Bay.

Plant owners retained the services of TRC Environmental Corporation, and EarthTech, Inc. to conduct an evaluation of the major alternative to present single pass cooling, mechanical draft cooling towers. Mechanical draft cooling towers provide cooling through both sensible and latent heat transfer. Cooling water, in this case salt water extracted from the Bay, would be passed through the plant to absorb waste heat from the process, much as it is today. But instead of being discharged to the Bay as presently happens, the heated water would then be sprayed at the top of the cooling tower, and droplets of spray would travel down to collection trays at the bottom of the cooling tower, where the water would be recycled to the plant. Meanwhile large fans located at the top of the cooling tower, would draw air in a counter-current to the falling droplets. As the air contacts the droplets, it cools the droplets in two ways: sensible heat transfer and latent heat transfer as a result of some evaporation of the water in the droplets. Although some water would still be required from the Bay and discharged back to the Bay after circulation in the cooling tower, the quantities would be much lower and the water would be discharged at a much cooler temperature, thus eliminating the thermal impact of the plant to the Bay.

The operators of the plant have expressed concern with installing cooling towers at the plant due to the environmental impacts of the cooling towers. TRC and EarthTech focused their evaluation on one very important aspect of these impacts: the creation of fog and ice. MFG's role in this process was to evaluate the work of TRC and EarthTech and to provide an independent view of the environmental impacts of the potential plant modification to use cooling towers instead of single pass Bay water.

Many of the environmental impacts resulting from cooling towers stem from the emission of water vapor from the cooling tower. The majority of the cooling of the water in the cooling tower results from the latent heat of vaporization. Essentially, the waste heat from the plant would be used to evaporate water. The water vapor is discharged to the atmosphere. Air exiting a cooling tower will almost always be fully saturated with water vapor (e.g.; 100% humidity). It will also be hotter than the surrounding air as a result of the sensible heat transfer in the tower. As soon as it contacts the outside air the exhaust from the cooling tower will begin to cool and as it does, it's ability to hold water vapor is reduced, and virtually all cooling towers will be seen to have some condensed plume of water vapor at the exhaust. As the plume travels downwind it mixes with surrounding air and eventually comes to equilibrium with the surrounding air. If the surrounding air has a fog already, then the plume will contribute to that fog but will be virtually indistinguishable from the surrounding air. However, in most cases, there is no existing fog and as the plume comes to equilibrium with the surrounding air the plume re-evaporates and no condensed moisture is present. So in most cases, the plume condenses immediately after exiting the cooling tower and then re-evaporates at some downwind point. Most of the time the condensed plumes remain aloft and evaporate before contacting the ground. The length and width of this condensed plume varies from moment to moment as the meteorological conditions change.

The key impacts evaluated by TRC and EarthTech occur when the condensed plume comes in contact with the ground. This can occur because ground with a higher elevation than the plume lies downwind of the plume, or more commonly because winds cause the plume to be bent over and mixed to the ground. The condition is called "fogging" because a ground-level fog is produced by the plume from the cooling tower. Fogging conditions can cause impacts to neighboring land uses, such as the impact when fogging conditions occur on a roadway and potentially impair driver visibility.

A more severe concern is a special case of fogging called "icing," where plumes actually freeze on contact with the surface. Icing conditions can create a layer of sheer ice on the surface and present an even greater hazard to moving motor vehicles.

TRC and EarthTech used computer models to simulate the behavior of plumes from potential cooling towers at the Brayton Point facility. They estimated the number of hours fogging and icing would occur each year in the vicinity of the plant if the switch were made to cooling towers. They then examined a program to mitigate the fogging and icing episodes by assuming the plant would need to curtail operations during times when fogging and/or icing were likely. This resulted in estimates of hours of curtailment that would be necessary to switch the plant from the present system to a cooling tower system. The plant operators have offered these estimates as evidence of both economic and disruption impact to the plant from making this change.

MFG has reviewed the TRC and EarthTech documentation on their analysis and conclusions. It should be said at the outset that insufficient information was provided by TRC and EarthTech to allow their analyses to be reproduced, so the full details of the TRC/EarthTech analysis have not been reviewed by MFG. MFG has based its analysis and conclusions on the information that was available. In some cases we have been forced to make assumptions or guesses at what TRC or EarthTech did. We have attempted to document those where appropriate. We have divided the comments into a series of subheadings to improve readability, but many of the issues are inter-related.

Thermal Requirements/System Design

The first comment we would make concerns the system design and thermal requirements for the cooling towers. TRC and EarthTech have described a system that will require 72 cooling tower cells to provide the total cooling capacity for the Brayton Plant. However, TRC's report only considers a limited 20-cell system. They discuss conclusions about a larger system that would require 72 cells but provide no details of an analysis of such a case. Further TRC has assumed that each cell of the cooling tower system will reject a total of 1.43×10^8 Btu/hr of waste heat.

EarthTech reports they evaluated the full 72-cell system, but they provide no information in their report on how much heat is rejected per cell or by the system as a whole. MFG has assumed that EarthTech used the same 1.43×10^8 Btu/hr per cell used by TRC. In MFG's experience, cooling tower cells in use for large electrical generation plants tend to be of similar size and construction. We compared the heat rejection per cell used by TRC/EarthTech with other electrical generation facilities we have worked on and found the TRC/EarthTech value to be somewhat lower than the other projects, but this may be explained by the higher humidity of the Brayton Plant location than the mostly western US locations of the other cooling towers. We conclude that the value 1.43×10^8 Btu/hr per cell used by TRC/EarthTech is a reasonable value.

When applied to the full plant design of 72 cells, this computes to a heat rejection rate if all 72 cells are running of 1.03×10^{10} Btu/hr for all cells. If this were to continue for the entire year with all cells running continuously at full load as EarthTech has assumed, the total heat rejection would be 9.02×10^{13} Btu/yr or 90.2 TBtu/yr. The plant reports only 37.6 TBtu/yr currently rejected to the Bay so this gives an indication that the assumptions used in EarthTech's modeling are much greater than the actual heat rejection of the plant.

Of course it is understood that the design of a plant and the cooling requirements are not based on average or actual heat rejection, but on the maximum capacity of the system when running at the full 1600 MW. But even at that maximum rate, MFG believes too much cooling has been assumed. Without the precise details of the plant's design or efficiencies, it is not possible for MFG to conduct a comprehensive analysis of the cooling tower design, but we did compute a rough approximation of maximum cooling tower needs based on our knowledge of power plants and our experience with similar systems elsewhere. The details of these approximations can be found in Appendix A. As the appendix shows, we compute a maximum number of cooling tower cells needed, even with all units running at full load and a total of 1600 MW being generated of just over 60 cooling tower cells.

The numbers of cells assigned to particular units at the plant appears inconsistent to MFG. Units 1&2 have a combined generation capacity of 500 MW, while unit 3 has a larger generation capacity of 650 MW. Yet 30 cooling tower cells are assigned to handle the cooling load for Units 1&2 while only 22 are needed for Unit 3. We recognize there may be some differences in efficiency between Units 1 and 2 and Unit 3, but the difference in number of cells seems extreme, if all cells are equivalent. It is possible that the cells for Units 1&2 are smaller and reject less heat than those for Unit 3, but this is not indicated in either the TRC or EarthTech reports and based on the discussions provided by TRC we suspect that all tower cells were modeled with the same size and capacity in all analyses. It is likely that single cell parameters (water emission rate, exhaust volumes, exhaust temperatures) were developed for a cell of the 1.43 x 10^8 Btu/hr size, and simply used for all cells in the system.

But based on the design of the system it is clear that this value is too high. Section 3.3.1.1 of the design document gives the hot water and cold water temperatures as well as the water circulation rates. An approximate estimate of the heat rejection in the tower can be made by multiplying the difference in temperature (in degrees F) by the water circulation rate (in gallons per hour) and then by the density of water (assumed to be 8.33 pounds per gallon). Doing this calculation for Units 1&2 we get only 0.73 x 10^8 Btu/hr per cell. Similarly, we get 1.18 x 10^8 Btu/hr per cell for Unit 3 and 1.17 x 10^8 Btu/hr per cell for Unit 4.

Based on the design considerations above, we conclude that it is likely that the TRC and EarthTech cooling tower studies were performed with assumptions involving much greater water vapor emissions than would ever occur at the Brayton Point station if it were converted to mechanical cooling towers. The quantity of water vapor assumed to be emitted is the most important input in the cooling tower modeling performed by TRC and EarthTech. If the water vapor emission rate is overestimated, it may lead to an overestimation of the cooling tower plume impacts.

CALPUFF Model

The analyses conducted by TRC/EarthTech of the fogging and icing episodes used the CALPUFF air quality model. MFG is very familiar with the CALPUFF model, having used it in numerous previous projects to compute concentrations of air pollutants emitted by a variety of sources. In our opinion the CALPUFF model represents a significant advancement in the science of air quality modeling over previous models, most of which are based on the Gaussian Plume formulation that is in turn based on a steady-state atmospheric assumption. It is clear to MFG that the atmosphere is poorly represented by the steady state assumption and Gaussian Plume models have large errors. The CALPUFF model allows the wind conditions to vary spatially and allows the complex process of transport and dispersion to be simulated in a much more realistic manner than the older Gaussian methods. In MFG's opinion the CALPUFF model should be capable of addressing all dispersion scenarios more effectively than the older Gaussian methods, including dispersion of water vapor.

There are, however, unique aspects of modeling water vapor plumes that would require adaptations of the CALPUFF model. The standard version of CALPUFF available to all on the internet does not contain these adaptations. It is understood from the documentation that has been provided by EarthTech, the developers of CALPUFF, that these adaptations have been made in a series of subroutines that 1) pre-process the input meteorological and emission source data to provide an hourly emission file, and 2) post process the computed concentrations of water vapor to determine condensation, a critical element in determining fogging and icing impacts. However, the subroutines that have been developed by EarthTech to perform these tasks are not available to the general public. In fact EarthTech reports that the version of CALPUFF used for cooling towers is only available internally within EarthTech. We do not believe these adaptations have undergone peer review and been accepted by the modeling community at large. The perception created by TRC/EarthTech in their reports, that CALPUFF is a standard or accepted method of evaluation for cooling towers, is not correct.

MFG's concern in this regard is that the CALPUFF adaptation to cooling towers has not undergone the review and scrutiny of the CALPUFF model itself. We cannot be confident of the results from this analysis without further examination and testing of these adaptations themselves. While we have great confidence in the CALPUFF model itself, its use in this adaptation is new and untested.

Given that we do not have the program and cannot run independent tests to confirm the TRC/EarthTech results, it is difficult for MFG to comment on the accuracy of the CALPUFF modeling. There are however a few comments we will offer.

First, regardless of the accuracy of the model itself, there are inherent inaccuracies in the input information. As noted above, errors in the estimation of emission rates will contribute to the accuracy of any modeling study. But there are also errors in the meteorological data, and on the thermal characteristics of the plume itself as it is emitted. At best these models are thought to produce an error of roughly 50%, when emission rates and other data are well known. These errors increase when there are uncertainties in the input information.

Second, the analysis failed to adequately consider background fog or ice conditions. If an area is already experiencing fog from natural conditions, the added fog produced by the cooling tower would not be a significant impact. In fact fog is very common in the vicinity. Examination of meteorological data for T.F. Green Airport in Providence, the same data as used by TRC/EarthTech in the CALPUFF analysis, shows that fog occurred almost 18% of the time as reported at the airport.

TRC acknowledges this issue by stating in the September 2001 report that, "Comparison of the reported weather conditions for each hour allows isolation of those events where adverse conditions caused by the cooling tower may result solely from the cooling tower plume." But later in that same report (Section 2.2) TRC changes course and states, "However, to the extent that the goal is to develop an objective set of meteorological data to control tower operations and eliminate tower impacts, shutting down the tower may be necessary when ambient conditions are similar to plume induced conditions." So the implication is that, regardless of what the ambient conditions were, if the model predicts a plume-induced fog, TRC assumed the plant would have to be shut down.

It is less clear what EarthTech did. In the Schulman letter of October 4, 2002, EarthTech states, "Natural fog occurrences were not counted in the analyses." But later they state that, "Hours with 100% ambient relative humidity were excluded because natural fog would be present." But examination of 4 years of meteorological data (90-93) from T.F. Green airport shows that fog occurs many times without the relative humidity being 100%. In fact natural fog conditions were observed at T.F Green 6,213 hours during this 4 year period, but less than 20% of them had a relative humidity of 100%. So the conclusion is that EarthTech's usage of the 100% relative humidity condition as an indicator of the presences of fog is a poor choice and will lead to an underestimate of the number of hours of natural fog. Consequently, it is likely that many of the hours predicted as being plume-induced fog by EarthTech and requiring a plant shut down, may have actually had a natural occurring fog and should have been removed from the analysis according to EarthTech's stated procedure that, "Natural fog occurrences were not counted in the analyses."

MFG also examined specific days in the TRC analysis when the model reported that a fogging condition would occur. We found that on many of the days TRC reported as having a plant-induced fogging conditions, a natural fog already existed. For example in the results for 1990, TRC reported plant-induced fogging on 7 different hours. A total of 8 hours of fogging conditions were reported over these 7 days. But MFG determined that for all 8 hours in TRC's table for 1990, a natural fog was present in the area already. Contrast this finding with TRC's description of these conditions in the October 3, 2002 report, "without warning, under clear sky conditions." It is clear that none of these conditions predicted by TRC in their modeling for 1990 were under clear skies. This certainly poses the question of whether a plant shut down would be necessary to avoid a fogging condition when a fog was already present. Not all the years are as dramatic as the 1990 data. For example, in 1993 TRC predicted fog on 3 different days encompassing a total of 7 hours, and MFG found a naturally occurring fog was present on 2 of the 3 days and 5 of the 7 hours. But TRC also reported icing conditions on 4 additional days that year, covering a total of 5 hours. MFG's examination of the data showed only one of these days (and only one hour) reported a condition (heavy snow) that would make icing less important.

It is not certain that all days with fog should be eliminated from the mix because fog can occur to varying degrees and in some cases the added fog of the cooling tower could aggravate a fog situation, taking it from a non-hazardous driving condition to a hazardous one. But the same is true in reverse. Not all plant-induced fogging conditions will produce hazardous driving conditions. TRC has assumed any condition with condensed moisture would present a fog of sufficient density to create a driving hazard. MFG believes there are cases when the plume could be partially condensed, but not sufficiently opaque as to create a driving hazard. We believe some consideration should have been given in the TRC analysis to natural occurring fog, ice and snow, and that the estimates of fog-causing conditions in the TRC analysis include many days when the plant likely produces little change from existing conditions.

In addition, TRC suggests the plant would need to be shut down for many hours beyond just the hours of fog and ice predictions. They argue that to avoid any possibility of fog, the plant would be required to shut down in advance of fog forming on the basis of meteorological conditions that favored fog or ice formation on the bridge or I-195. The conducted a separate analysis using specific criteria to determine the number of hours the plant would be shut down using a predictive model. In their predictive model, they would shut the plant down any time the wind direction fell between the vector angles of 35 degrees and 135 degrees. *[Note: these angles are all measured clockwise from north and refer to the direction towards which the wind is going.]* These angles encompass a much larger sector than appears to be necessary on the basis of the modeling. TRC only predicted impacts on the bridge during a very narrow set of wind vectors, from 109 degrees to 118 degrees. Similarly, impacts on I-195 were only predicted during wind vectors from 36 to 68 degrees. If TRC had used narrower ranges of wind vectors, the analysis would have shown fewer hours of shut down were required. Of course this comment applies only to the 20 cell tower evaluated in TRC's September 2001 report. The discussion of the 72-cell tower analysis provided in TRC's October 2002 letter did not provide the same level of detail as the earlier report and it was not possible for MFG to evaluate the wind angles for the 72-cell case.

MFG believes it is likely that the same concerns expressed above, apply to the EarthTech report as well. However, EarthTech did not provide sufficient detail in their report to allow an evaluation of specific days.

Analysis with the SACTI Model

MFG has conducted numerous cooling tower analyses with an older computer model called SACTI, developed originally by Argonne National Laboratories for the Electric Power Research Institute. The SACTI model was written in the early 1980's and uses the older Gaussian Plume formulation for calculating plume dispersion. It is also written in an older style computer code and the program has a number of "bugs" that the user must avoid.

We do not assert that the SACTI model is superior to CALPUFF for this application. In fact the SACTI model has limitations that make it very difficult to use in the current application. For example the model is presently limited to no more than about 25 cooling tower cells, making the analysis for the 72 cell case impossible without major re-working of the computer program. None-the-less, the SACTI model has a long history of use for cooling tower applications and MFG believes it is interesting to examine how predictions using the SACTI model would differ from those offered by TRC/EarthTech. If the SACTI model were to support the CALPUFF results, it would provide independent support for the TRC/EarthTech analysis.

MFG ran the SACTI model for the same 20 cell case examined by TRC. We attempted to use the same assumptions as TRC used, so that the only difference would be the change in model. We did not remove hours of natural fog in our analysis. We used the same meteorological data as TRC although we only ran one year (1990). The result of the analysis is that we predicted 5 hours of fog on Interstate 195, and none on the Braga Bridge. This is considerably less than the 17 hours of fog predicted by TRC including 11 hours of impact on the Bridge.

In addition, separate runs of the SACTI model were made to evaluate the 20-cell cooling tower at a different location, on the western portion of the property. The 20-cell cooling tower was placed in the open area to the southwest of the generating units. The results showed significantly less impact on I-195. The area impacted was smaller and the number of hours with impacts on the roadway were fewer. Although it is impossible for MFG to evaluate the cooling towers with the CALPUFF model since EarthTech has not released that version of the model to the pubic, we would expect the conclusions with the CALPUFF model to similar, in that fewer hours of impact to I-195 would occur with the towers re-located to the southwest of the generating units.

MFG was unable to examine the full 72 cell case with the SACTI model without a major revision to the model. Internal aspects of the SACTI model limit it's practical application to about 25 cells. Evaluation of more cells leads to model failure. Simple re-compilation with expanded array sizes was attempted but was unsuccessful. We do not suggest that the SACTI model predictions are more reliable or accurate than the analysis conducted by TRC/EarthTech with the CALPUFF model. However, we do state that the results of the TRC/EarthTech analysis are not reproduced by the SACTI model and that in fact very different conclusions including much less impact would be concluded if the analysis had been performed with the SACTI model.

Consideration of Alternatives

MFG believes that the analysis conducted by TRC/EarthTech for the potential cooling towers has used certain narrow assumptions that have lead to their conclusions. It is assumed, for example that the plant would be required to shut down during meteorological conditions that might cause fogging or icing on the Braga Bridge or other portions of I-195. Furthermore, TRC assumes that in order to avoid such conditions that the generating units would be required to shut down any time the meteorological conditions favored the possible fogging condition, further expanding the number of hours needed for shut down. This latter restriction greatly expands the number of hours the plant would be required to shut down.

It is important to note that the proposed program of shutting generating units down to avoid fogging and icing conditions is not something required as part of a permit from a government agency, but rather is being offered as a step the station operators would take to avoid endangering the public. As a voluntary program, station operators would have a great deal of flexibility in when and how to implement the program. If they found that the model over-predicted impacts for example and that plumes did not affect the bridge or I-195 in any significant way, they would be free to relax or modify any requirements to shut the generating units down.

There are other steps that might be taken to minimize plume impacts. Impacts might be minimized by siting some of the cooling towers further from the bridge on the southwest side of the plant. The station operators might shut down some of the generating units, but not all of the generating units. The impacts of fogging may be overstated for the various reasons noted above, and a re-analysis with hours of natural fog removed might show much fewer hours of fog or ice that might be considered acceptable and not posing a significant risk to the public.

The station operators may also consider further mitigation to the towers themselves. Mitigation and alternatives are available. First, dry cooling is a technology used at some plants. The size of this plant is large enough that dry cooling would require a great deal of space and expense, but it is a possibility. A more likely possibility is a combination of some dry cooling and some wet cooling. In such cases the dry cooling can be used to offset some of the impacts of the wet cooling, and can be used in particular during periods of the year when fogging and icing conditions are most likely to occur.

There are special types of cooling towers that offer plume mitigation. Essentially these towers include some dry cooling within the tower itself that heats the plume prior to exhaust. This additional heat boosts the plume height, raises the temperature of the plume so that the relative humidity falls below 100% and can minimize the length and width of the plume.

Also worthy of consideration are combination systems that allow some heat rejection to the Bay to continue, but provide cooling towers for the remainder of the heat to be rejected. This follows the concept of the multi-mode system evaluated by TRC.

Conclusions

MFG's overall conclusions from review and evaluation of the TRC/EarthTech materials are summarized as follows:

1. Insufficient information is available on which to conduct a comprehensive review of the analyses

2. TRC/EarthTech likely used a cooling tower configuration that is more expansive and involved greater heat rejection than would actually be required for the plant.

3. TRC/EarthTech likely overstated the impacts of the cooling towers on fogging and icing due to failure to adequately consider existing fog and ice/snow conditions.

4. The focus of TRC/EarthTech's analysis was limited only to fogging and icing. Although TRC briefly discussed other impacts, they provided no technical analysis of impacts of plume visibility and plume shadowing, or salt and water deposition. Furthermore their analysis focused on wet cooling towers only and did not consider dry cooling options or hybrid systems.

5. TRC/EarthTech assumed the plant would be required to shut down for extensive hours to avoid fogging and icing impacts when it is not clear that such a program

would be required by any governing agency, and there are alternatives to mitigation of the plumes that were not considered.

Appendix A

Calculation of Thermal Load and Number of Required Cooling Towers

Brayton Point Cooling Tower Analysis
Calculations from Kirk Winges

Purpose: Calculate the heat rejected to the Bay

Key assumption, energy balance

Energy in input fuel = Electricity generated + Parasitic Loss + Heat Lost to air + Heat rejected in Bay

Further Assumptions:

Efficiency = (Electricity Generated)/(Energy in Input Fuel)
= 35%
Parasitic Loss = 4.93% of total of Electricity generated + parasitic loss
(based on data in e-mail - Plant-Level Generation Table)

So reform the energy balance

Heat rejected to Bay = Elec. generated/efficiency – Elec. Generated - (.05185)(Elec. Generated) - Heat Lost to air
Heat rejected to Bay = (2.8571 - 1 -.05185)(Electricity Generated) - Heat Lost to air
Heat rejected to Bay = 1.80529651 Electricity Generated - Heat Lost to air

Calculate Heat Lost to Air:

Not much to go on here, but make some assumptions

assume inlet air is	50	deg. F
assume exhaust is	300	deg. F
delta temp in air	250	deg. F

(note: I recognize that inflow and outflow are not the same, but since 80% of the air is nitrogen and the nitrogen just passes through in the combustion process, it's a reasonable assumption for a "back of the envelope" calculation that the sensible heat lost to the air is represented by a temperature increase in the exhaust air.)

Heat capacity of air is approximately 0.238 cal/(gram-deg.K)
= 0.238 Btu/(lb-deg. F)

How much airflow in exhaust gases? Don't have any idea, but guess on basis of Centralia Power Plant here in Washington, where a 670 MW unit had an exhaust stack with a 24 foot diameter and an exit velocity of 101 feet per second.

Centralia flow = 45691.285 ft3/sec
So, scaling on MW = 68.1959477 ft3/(sec-MW)

Now, for Brayton Point at 1600 MW:

Flow = 109113.516 ft3/sec

Now we need to convert to a mass basis:

use ideal gas law -- PV=nRT

n =	PV/RT	
	(1 atm)(109113.5 ft3/sec)/[(0.7302 atm-ft3/lb-mole-deg R)(300 + 459.67 deg. R)]	
	196.7033458 lb-moles/sec	
assume exhaust is 29 lb-lb-mole		
	5704.397027 lb/sec	
=	20535829.3 lb/hr	

Finally, put it all together

Heat lost to air = (pounds of air)(heat capacity of air)(delta T)

=	1221881843 Btu/hr	
=	358.0186478 MW	(@ 1600 MW generation rate)

So now we have all parts of the equation:

At full generation - 1600 MW

Electricity Generated	1600 MW
Heat Lost to air	358.018648 MW
Heat rejected to Bay	2530.45576 MW

So, we develop the following ratio: 1.58153485 Waste heat to Bay per unit of electricity generated

Using this ratio for 2001:

	8205951 MW-hr total generated
	12977997.51 MW-hr rejected to Bay
=	44292607.69 MMBtu rejected to Bay
=	44.29260769 TBtu rejected to Bay

Number of towers needed at full load:

Energy rejected to Bay at full load =	2530.45576 MW
Energy rejected per tower =	1.43E+08 Btu/hr
	41.8998506 MW rejected per cell
Number cells needed	60.3929544 cells